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Morris Ebert.
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THE STANDARD SILICA CEMENT CO.

Glens Falls, N. Y.

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Tests of Silica Portland Cement

New York Office 156 Fifth Ave.

CHAS. H. SPENCER,
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[This paper is now two years old and the Silica Portland Cement, with which the tests given in tables were made, was much more coarsely ground than obtains at the present time. Then 20 per cent. of the mixture was rejected by No. 180 sieve, about 32000 meshes per square inch, now only 5 per cent. is rejected by this sieve.]

About the Sandcement

Of Messrs. F. L. SMIDTH & Co., Copenhagen.

By A. FOSS, C.E., M.Ing. F. and C. ENGLEHART, C.E., M.Ing. F.

For almost every kind of building operation where bricks or stone form the chief building material, mortar is required to join together the loose parts which are to form the whole structure.

The nature of the chief building material varies to a great extent, according partly to the nature of the work and the purpose which it has to serve, and partly with the facilities of getting certain materials in preference to others.

These materials may therefore be in the shape of dressed stone, rough stone, bricks, or rubble, ballast, gravel, or the like.

With the mortar the choice is, generally speaking, only between lime and hydraulic cement. The qualities which are necessary in a good mortar are that it will "set" or harden into a substance of great strength, that it will adhere firmly to the surfaces, which it joins together, and lastly that it will preserve its hardness and solidity under the atmospheric and other influences to which it may be subjected.

SETTING.

The setting of both lime and cement is due to chemical changes in the interior, but in these two materials the setting is of distinctly different nature.

In the lime the setting is due to the absorption from the atmosphere of carbonic acid gas, which enters into compound with the calcium of the hydrate of lime, forming carbonate of lime, and at the same time giving off water. This setting of lime mortar is then dependent on the access of the atmospheric air, containing carbonic acid gas, and this explains that the setting of the mortar in thick walls proceeds from the surface inwards, and makes slower and slower progress the further it proceeds, so that very thick walls built hundreds of years ago are found to contain in their interior fresh and soft mortar, and it also explains that lime mortar will not set under water.

The giving off of water by the chemical process of the setting of the lime explains why walls and whole houses, built in lime mortar, remain damp for such a long time, rendering new houses unhealthy and almost uninhabitable.

The setting of the Portland cement on the other hand is due, according to modern researches, to the presence in this of tricalcium-silicate, SiO_2, $3CaO$, which forms the constant crystalline silicate, SiO_2, CaO, $2.5H_2O$, which is the real strength-giving element in the hardened cement. At the same time the calcium-aluminate, formed by the calcination of the cement, takes up more lime, again under absorption of water, and forms the constant and crystalline Calcium-aluminate, Al_2O_3, $4CaO$, $12H_2O$.

Le Châtelier* has first cleared up the true nature of the setting and hardening of the cement, as set forth in the above. He further proved that the "setting," which is a rather sudden change, taking place sooner or later, according as the cement is quick or slow setting, is due to the formation of the Calcium-aluminate, whereas the ultimate hardening, or increase in absolute strength is due to the Calcium silicate, as has already been said.

His theories have been universally accepted, and much light has been thrown on this question of setting of the cement, till then very obscure.

MORTAR,

Consists of sand mixed with the lime or the cement, and with an addition of water to bring it into a suitable consistency.

As the interstices between the sand-particles fill nearly one-half of the whole volume, absolute density is only obtained when equal parts of sand and cement are taken. With lime the case is somewhat different, as the water adds considerably to the bulk of the hydrate of lime, and the absolute filling of the insterstices would be attained with considerably less lime. Practically, however, a smaller quantity of cement as well as of lime is sufficient to make a good sound mortar, and the usual thing is to mix strong cement-mortar of one part of cement to three parts of sand.

Portland cement, as it is generally sold, is ground to a certain fineness. This powder, however, consists of particles of varying size, often 8-10 p.c., is so coarse as to be left on a sieve of 2500 meshes to the square inch, 20-25 p.c. pass through this, but is left on a 4900 mesh sieve, and of the rest a part only can be said to be a perfect or impalpable powder. The value of fine grinding has been amply proved, and it is quite evident that the cement will go further if finely ground, firstly because the coarse particles do not set at all by themselves, but remain impassive as so much sand added, and partly because the greater the number and the finer the particles, the more surface of sand will they be able to cover and join together.

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*Annales des mines, Paris, 1887.

In order to make a strong and reliable mortar, the interstices between the sand particles should be fairly filled with the cement, and this is evidently only attained when firstly there is a sufficient quantity of cement in the mortar, and secondly when the cement is evenly distributed in the mortar. To use a large quantity of cement and then mix it carelessly, so that in certain portions of the mortar cement is abundant, and in others there is little or no cement, is a waste of the expensive cement, and gives no safety to the work built in such mortar.

By careful mixing and by using finely ground cement of a good quality, good reliable mortars can be made with less cement than that mentioned above, viz., 1·3, but it is not safe to go too far in the proportion of the sand to that of the cement. It is hardly safe to use a cement mortar 1·6 or 1·8 even when the utmost care is taken in the thorough mixing. It must here be remembered that the strength diminishes at a much quicker ratio than the quantity of cement expended, and the care and trouble in mixing ought to be increased at such a ratio as to make the thing impracticable. The adhesion of these meagre mortars to the stone or brick is also very small.

For these reasons it is, in very many cases, necessary to use a cement-mortar of a far greater strength, and consequently far more expensive than what is really required, if it is not considered advisable to go with a leap right down to lime-mortar with its many defects, such as slow setting and drying, and very small absolute strength.

Something may certainly be done by hybrid mortars of cement and lime, but here, if the quantity of the cement is reduced as before, the same difficulty in distributing it, and the same great care in the preparation of the mortar, are again in evidence, if the mortar is not finally to consist of parts containing cement in abundance and parts containing none at all.

There is evidently a strong want for a method of making mortar, combining the low price of lime mortar with the strength and resistance of cement mortar.

Considerations of this nature led Mr. F. L. Smidth, C.E., of Copenhagen, to invent a novel way of utilizing Portland cement.

The idea of his invention for which patents have been granted to him in all countries, and which he has named "Sandcement," is very simple, and the excellent results obtained thereby are easily explained. Portland cement and sand are well mixed and then pulverized in a dry state together.

The result is the "Sandcement," which is then used as ordinary Portland cement, *i.e.*, mixed with usual sand and water to form a mortar.

The object is a double one, firstly the fine reduction, and secondly the thorough and intimate mixing of the two constituents.

In a mortar made with Sandcement by addition of usual coarse sand, the interstices between the particles of the latter are filled with Sandcement, and the interstices between the fine sand particles of this are in their turn filled with cement, and this is done in a far more satisfactory manner than in usual mortar, because the sand and cement are ground together and therefore very intimately and evenly mixed. The amount of interstices between the sand is thus vastly reduced, and the cement is finely pulverized, thus increasing the number of particles of cement, and moreover these cement particles are evenly distributed so that they are present everywhere in the mortar.

The advantages, theoretically, are obvious, and the results of the trials, practically, have even surpassed the most sanguine expectations.

The trials have been effected with Sandcement of the most varying ratio of cement and sand, from one part of cement with one part of sand, down to one part of cement with twenty-four parts of sand, and these Sandcements have been tested according to Danish and German standard rules for testing Portland cement, though with the difference that usual sea sand or other clean natural sand was used instead of normal sand, both for the production of the Sandcement and for the making up of the test-briquettes.

The tests are made partly by Mr. N. P. Nielsen, C.E., at the official testing laboratory in connection with the Polytechnic College at Copenhagen, and partly by Dr. Erdmenger, Hanover, Mr. C. Buch, chemist at Aalborg Cement Works, and Mr. Carlsson at "Skaanska Cement Aktiebolagets" laboratory at the Limhamn Works.

In addition to these, tests are being carried on at Helsingfors, Finland, at St. Petersburg at the official laboratory for testing building materials in connection with the Military High College, by Professor Bjelelubsky, also at the laboratory of the Cement Works Stern at Stettin, and in London by Mr. H. K. Bamber, of Victoria Street, Westminster.

Of this very great number of tests we shall here give the results reported by Mr. N. P. Nielsen, in the table affixed. The experiments cover setting under water as well as in the air, and tests as to tensile as well as crushing strength, and they are carried over a length of time up to one year. In all about 1,300 briquettes have been tested in this series.

In the table the two first columns show the ratio of cement and sand in the Sandcement, the third gives the number of parts of coarse sand added to one part of the Sandcement in question. In the following the formula

(1:3):2 is to be understood as one part of cement and three parts of sand made into Sandcement, and one part of Sandcement mixed with two parts of coarse sand. If it were concrete this would be written 1:3:8, but we prefer to write it (1:3):2 in analogy with the usual way of indicating cement mortar, the cement in this case being Sandcement (1:3). The mortar (1:3):2 really contains in all eleven parts of sand to each part of cement.

The numerous tests and trials made could provide material for much more of these interesting comparisons, but we think that we have already shown enough to prove the great advantage of the new method.

The next question which naturally crops up is this: Are these results which, after all, can only be considered as theoretical results obtained in the laboratory, confirmed by practical experience? and what practical value can be ascribed to them?

Naturally the material at hand to answer these questions is as yet but limited. But such practical experience and such practical trials as have been made as yet, all tend to confirm the high expectations in the most emphatic manner.

In giving these results and further mentioning the qualities wanted in a mortar-material according to the various uses of it, we shall keep separate the three chief groups of such work, namely, usual building work, foundations, and strictly hydraulic work.

A.-SANDCEMENT FOR USUAL BUILDING MORTAR.

After the experiments already recorded, the idea is near at hand to use Sandcement mortar for usual building work, brick work, &c., when at comparatively smaller cost greater strength is obtained than that of ordinary lime mortar, and to this is added the advantage of much quicker setting and drying, a great deal is gained by letting the Sandcement take the place of the lime. Moreover, a series of practical trials have proved the unexpected fact that the Sandcement mortar is equally sleek and agreeable to handle with the trowel as lime mortar, provided the Sandcement is of sufficient fineness. The sleekness of the lime mortar is probably not so much due to real plastic properties of the lime, as to the state of very fine sub-division in which it is present, though something may be due to the great faculty of the lime to absorb and retain moisture.

For ordinary building purposes Sandcement mortars of very varying ratio of mixture have been used, extending from (1:12):3, containing fifty-one parts of sand to each part of cement, and up to (1:6):1½, containing 16½ parts of sand to each part of cement. With the first mentioned a building for a laboratory has been erected at Limhamn Cement Works in Sweden, giving full satisfaction.

Mr. Lytthans-Petersen, a master builder of Copenhagen, used Sandcement mortar (1:12):2, containing thirty-eight parts of sand to each part of cement, to build a gable end of a house, then during erection at Klampenborg, near Copenhagen. The gable end in question was situated due east, and close to the sea. Immediately after completion of this gable end, frost set in, and after two months exposure, during which the building operations were stopped, on account of the hard frost and severity of the winter, this brickwork was found on examination to be perfectly sound and much stronger than other parts of the walls built two months earlier in ordinary lime mortar.

In the new pumping station of the sewage works of Copenhagen, Sandcement (1:6) has been extensively used, and with sand added at the rate of 1½, 1¾, 2 and 2½ parts to each part of Sandcement. These building operations were performed in the months of July and August in the hottest and driest summer weather. A few months afterwards it was found to be impossible to drive a nail into one of the joints of the brickwork.

Since then the Sandcement has been used for the basements of two public schools in Copenhagen, being erected under the supervision of the Borough architect, Professor Fenger.

As has already been pointed out before, the Sandcement possesses one very great advantage over lime in the quick setting and drying out, which is due to the nature of the chemical processes of the setting, water being absorbed in the case of the Sandcement to accomplish this, while water is given off in the case of the lime. The houses built in Sandcement being sooner inhabitable without risk to the health of the inhabitants, and without destruction by the moisture of woodwork, paperhangings, &c., means not only a material improvement but also a financial advantage, and for a large town the increase in interest on capital from this source may be enormous.

In "Ingeniören," the organ of the Association of Danish Civil Engineers, of February 10th, 1894, Mr. Hans Fr. Boje gives an account of the building of a dwelling house at Hulta, in Sweden. The house was built in Sandcement, the building operations being commenced at the end of May, the roof was raised at the end of July, and the people moved in at completion of the house on the first day of October. The house was found as perfectly dry and agreeable to inhabit as if it had been a couple of years old, and even the most delicate papers of the most sensitive colors on the walls never suffered the least damage. At the same time another house built in ordinary lime mortar, under the same conditions, remained damp for a long time, and much damage was done to the hangings, curtains, &c., as well as to the woodwork in windows and doors. That the inhabitants complained of the unhealthy moisture and smell of damp brickwork in that house for a long time after stands to reason.

Besides the great advantage of quick setting and drying of brickwork built in Sandcement, the advantage referred to above of being to a great extent independent of the frost in the winter will always prove of the very greatest value in all ordinary building operations, and it is well known that lime mortar cannot set during frost, and all building operations in which it is used must be stopped during times of frost, often causing the greatest inconvenience and heavy loss to the builder.

In order to form an opinion about the practical strength of Sandcement as compared to that of lime and hybrid mortars of lime and cement, Mr. G. Kaehler, C.E., made some tests with specially built piles of brickwork. The piles were built by racking the bricks out horizontally, by a journeyman brick-layer, on the 13th of September last year, care being taken that all joints were well filled with mortar.

On the 23d of the same month, just ten days after the samples were made, they were broken by hanging a bucket at the end of the last projecting brick, and weighting it until fracture ensued. The brick in question is, as will be seen, kept in position by the strength of the horizontal joint as large as half of the flat side of the brick and the vertical joint of the size of one of the end faces.

No. I was built in ordinary lime mortar, No. II in hybrid mortar of one Portland cement and five slake lime, and the others in Sandcement mortar of various composition, viz.:

No. III.	...	(1:8):2¼	...	1	cement and	28¼	sand.
No. IV.	...	(1:8):3	...	1	"	35	"
No. V.	...	(1:12):2	...	1	"	38	"

The breaking weights were :

No. I.	...	...	36 lbs.
" II.	...	...	111 "
" III.	...	...	118 "
" IV.	...	...	100 "
" V.	...	...	67 "

It is only fair to make the remark that the hybrid mortar in the small quantity as here used could be, and was made in a far more careful way than would ever be the case in actual work.

PLASTERING AND POINTING.

With regard to the use of Sandcement for plastering and pointing, it is evident that Sandcement would go in wherever cement is now used for plastering, and the strength of the former is sufficient. It would even have the decided advantage of combining a smooth surface as that of neat cement with the absence of surface cracks, always found where the latter is used. Over ordinary lime mortar for plastering purposes it would have the advantage of much greater strength, and quicker setting and drying. It is worth mentioning here an experiment made by Mr. O. Kjellstrom, C.E., Stockholm, who covered two specially built piers of brickwork with plastering of lime and of Sandcement mortar (1:20):1 and (1:20):2, containing respectively forty-one and sixty-two parts of sand to each part of cement, and after twelve days tested these coverings with a strong jet of water. It was then found that the lime plastering was easily washed away, whereas the Sandcement plastering of both kinds were only quite superficially damaged, the sand particles being, after protracted playing of the jet on one spot, washed clean.

This proves that Sandcement will have great advantages for outdoor plastering work.

B.—FOUNDATIONS.

For ordinary foundations for buildings, cement concrete is universally used, mostly containing cement, sand, and broken stone in the ratio 1:4:7 or 1:4:8. But provided the mixing of this concrete is anything like carefully done the strength of it is in most cases much greater than what is really required, and too much of the expensive cement is thus used. This will especially be the case where the subsoil is of sufficient firmness to carry the building, and where the foundations only have to act as the foot of the building.

If in such case the mortar of one cement and four sand in the concrete is substituted by (1:3):3½ Sandcement-mortar containing seventeen parts of sand to each part of cement, full required strength would no doubt be obtained.

There is yet another consideration in connection with this point. The Sandcement factories would, like the one already in full operation in Copenhagen, be prepared to supply, not only Sandcement, but also ready mixed dry mortar. This machine mixed mortar will do away with the careless hand mixing now generally practised, and everything considered it is not too much to say that this machine mixed mortar of (1:3):3½ in a concrete would be quite equal to hand mixed 1:4 Portland cement mortar. In this way the cost is reduced both as regards materials and labor.

It is well known that the strength of cement mortar and concrete is, to a large extent, dependent on the quantity of water added for making it up. It can generally be said that just enough water to fill up all the interstices in the mortar give the best result, and that all additional quantities tend to diminish the strength.

In a quite recent publication* examples are given showing that briquettes of one cement and three sand gave the best tests with 10 p.c. of water; when 12 p.c. of water was used the twenty-eight days tests for crushing strain fell by 40 p.c. and by 15 p.c. of water, the same tests fell by 65 p.c. (from 4,050 lbs. to 1,420 lbs. per sq. inch). Later tests, of course, show an improvement, but it is certain that the drier the mortar or concrete is prepared the better. Ten p.c. of water, however, only give to the mixture of cement and sand a moisture like that of moist earth, and ramming is therefore necessary. The ramming should be continued until the moisture shows on the surface.

The examples given show how very badly the Portland cement is generally utilised in practical work.

What is necessary in usual cement mortar is, of course, still more so in Sandcement mortar, where the very small quantity of cement only requires a very small quantity of water, still it must be remembered that the Sandcement after all has given very high tests, so that the influence of a surplus of water has not such a disastrous effect as might have been expected. It is only best to bear in mind when using cement or Sandcement for mortar or concrete, that the smallest quantity of water should be used, with which the mortar or concrete can be made up, and the concrete should be well rammed.

In preparing ordinary mortar for bricklaying, sufficient water must, of course, be taken to make the mortar suitable for work with the trowel, but the bricks will, in this case, absorb the surplus of water within a short time, and the ramming is in this case substituted by the pressure of the brickwork above.

C.—WORKS OF THE CIVIL ENGINEER.

What has already been said is to a certain extent applicable in the case of the more special works of the Civil Engineer.

It is often the case that the greatest absolute strength is necessarily required, and in such cases there would not be any reason to apply the new method.

Where the object, however, is to get a filling material of adequate

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* Der Portland Cement und seine auwendungen im Bauwesen, Berlin, 1893.

SANDCEM

Nr	Mixture by weight.			The Mixture contains		Crushing Strength. lbs. per sq. inch.												Finen Grin Resid
						In Water.						In the Air.						
	Cement	Sand	Sand	Cement	Sand		V.						L.					
	Sand-cement		Not grd		a	7 D	28D	90D	6M	2M	a × V.	7 D	28D	90D	6 M.	12 M	a × L	
1	1		3		3	1595	2360	3120	. .	5055	7080	1640	2500	3160	. . .	3720	7500	. . . . .
2	1		3		3	1165	1610	150	. .	967	4830	1 80	870	4 0	. . .	3295	5610	. . . . .
3	1		6		6	426	655	868	. .	1292	3930	526	952	1110	. . .	1760	5712	. . . . .
4	1	2	2	1	8	080	1795	2148	2578	3365	14360	1122	2150	1565	3330*	2911	17200	5800 mes 3 600mes
5	1	3	2	1	11	497	1080	1637	2008	2485	11880	610	1 75	1408	2022	3536	17545	. . . .
6	1	6	2	1	20	327	555	1025	1117	1363	11100	398	880	967	1209	1292	17600	. . . .
7	1	12	2	1	38	171	384	726	796	866	14590	256	610	654	768	767	23180	. . . .
8	1	24	2	1	74	128	270	370	370	383	19980	100	298	248	271	213	22050	. . . .
9	1	6	0	1	6	512	895	1380	. .	2357	5370	600	1120	1460	. . .	2258	6720	. . . . .
10	1	6	1½	1	16½	370	540	852	. .	1576	8910	440	940	960	. . .	1533	15510	. . . . .
11	1	6	2	1	20	200	384	667	. .	1050	7680	256	682	725	. . .	1079	13640	. . . . .
12	1	6	2½	1	23½	142	284	540	.	738	6674	200	5 8	583	. . .	710	13340	. . . . .
13	1	6	3	1	27	114	228	426	. .	582	6156	171	455	468	. . .	610	12285	. . . . .
5	1	3	2	1	11	497	1080	1637	2008	2485	11880	612	1595	1408	2022	3496	17545	. . . . .
14	1	3	2	1	11	640	1500	2136	2702	3081	16500	625	1780	1908	3160	3081	19580	. . . .
15	1	3	2	1	11	670	1220	1651	2462	2670	13420	725	1025	1671	2802	2868	11275	. . . . .
16	1	3	2	1	11	. .	. .	. .	. .	. .	. . .	780	1720	1820	2073	. . .	18920	. . . . .
	Test of Joint ⅜-in. thick																	
17	1	3	2	1	11	. .	. .	. .	. .	. .	. . .	2675	3120	3510	3791	. . .	34320	. . . . .
7	1	12	2	1	38	171	384	. .	. .	. .	14592	256	610	653	769	. . .	23180	. . . . .
18	1	12	2	1	38	. .	. .	. .	. .	. .	. . .	342	600	710	738	. . .	22800	. . . . .
8	1	24	2	1	74	. .	. .	. .	. .	. .	. . .	100	300	249	270	. . .	22200	. . . . .
19	1	24	2	1	74	. .	. .	. .	. .	. .	. . .	213	412	370	454	497	30488	5800 mes
	Test of Joint ⅜-in. thick																	
20	1	24	2	1	74	. .	. .	. .	. .	. .	. . .	1050	2000	2519	2698	3663	. .	. . . . .
21	Ordinary test					. .	. .	. .	. .	. .	. . .	11	65	182	284	. . .	. . .	. . . . .
22	Test of Joint ⅜-in. thick					. .	. .	. .	. .	. .	. . .	950	1560	1830	1903	. .	. . .	. . . . .

× 1·155 lbs. Sandcement and 2·3 lbs. coarse sand made up with ·04 gallons milk-lime.
OBSERVE.—The milk-lime contained 20% hydrate of lime by weight
Gave little residue after one hour's settling.

NT---TESTS.

*Residue 5800 Mesh per sq. in. 0·0%
" 31600 " " 20·2%
Sets in 8–9 hours.

Tensile Strength. lbs. per sq. inch.												Remarks.	
In Water.						In the Air.							
	V.						L						Quantity of water used for making up.
7 D	28D	90D	6M.	12M	a × V	7 D	28D	90D	6 M	12M	a × L		
256	327	412	. .	500	981	270	370	455	. .	611	1110	**Normal Sand**	9%
213	284	356	. .	356	852	284	370	426	. .	582	1110	Unwashed Copenhagener sand	9%
85	128	185	. .	200	768	114	185	213	. .	221	1110	Do do	9%
142	242	299	384	400	1936	185	356	356	526*	526	2848	*These briquettes were, during the last two months, eight times saturated with water	
114	185	228	271	326	2035	128	256	256	313	440†	2816	†These briquettes were, during six months, twenty-five times saturated with water.	
71	128	185	228	242	2560	114	242	242	242	242	4840	Unwashed Copenhagener sand. + Do do silver sand.	
43	114	128	157	142	4332	85	157	142	148	156	5966		9·2%
28	57	57	57	57	4218	43	71	57	57	57	5254		
85	114	185	. .	312	684	114	185	185	. .	213	1110		
71	114	185	. .	298	1880	100	200	200	. .	213	3300	Unwashed Copenhagener sand. + Do do do	
57	114	156	. .	220	2280	85	171	171	. .	156	3420		
43	86	128	. .	128	2020	85	128	114	. .	114	3008		
43	71	114	. .	142	1917	71	85	85	. .	99	2295		
114	185	228	271	326	2035	128	256	256	313	440	2816	**Same as No. 5.**	
142	242	280	327	356	2662	157	327	270	456	469	3597	Washed Copenhagener sand. + Unwashed do silver sand.	
142	213	265	327	376	2343	200	313	270	449	500	3443	Washed Aalborg sand. + Unwashed Copenhagener silver sand.	
. .	. .	. .	. .	. .	. . .	. .	. .	. .	. .	. .	. . .	Unwashed Copenhagener sand × + Do do silver sand.	
. .	. .	. .	. .	. .	. . .	. .	. .	. .	. .	. .	. . .	Do do do	
43	114	. .	. .	. .	4332	85	157	. .	. .	. .	5966	**Same as No. 7.**	
. .	. .	. .	. .	. .	. . .	. .	. .	. .	. .	. .	. . .	Unwashed Copenhagener sand × × + Do do silver sand.	
												Same as No. 8.	
. .	. .	. .	. .	. .	. . .	. .	. .	. .	. .	. .	. . .	Unwashed Copenhagener sand.	
. .	. .	. .	. .	. .	. . .	. .	. .	. .	. .	. .	. . .	+ Do do silver sand.	
. .	. .	. .	. .	. .	. . .	. .	. .	. .	. .	. .	. . .	Do do do	
. .	. .	. .	. .	. .	. . .	. .	. .	. .	. .	. .	. . .	Lime mortar containing 8% hydrate of lime (% of the dry weight), made of Faxe Pit-lime and Berlin normal sand + 10% water	
. .	. .	. .	. .	. .	. . .	. .	. .	. .	. .	. .	. . .		

× 1·155 lbs Sandcement and 2·31 lbs. coarse sand made up with ·035 gallons milk-lime.
nsisted of one volume ordinary Pit-lime with about one volume of water.

though not excessive strength, and where it is of importance to get a material of the greatest possible density, there is a wide scope for the use of Sandcement. It is interesting, in this respect, to remember that what was considered until a few years ago acceptable strength of strong mortar (1 cement, 3 sand) is now obtained by the use of Sandcement-mortar (1:3):2 = 1 Cement + 11 S.

There is, moreover, one special case where the Sandcement promises an actual improvement, on account of its density, and that is in works in the sea. Concrete is by far the most important agent for such works, especially where large and heavy blocks are required.

Ordinary concrete is, however, subject to the chemical influence of the sea water. The calcium aluminates of the cement are decomposed by the magnesium chloride and magnesium sulphate in the sea water, forming calcium chloride and calcium sulphate, which are soluble, and at the same time hydrate of magnesium and alumina, which are precipitated as fine powders, and easily washed away where the water has an opportunity of alternately entering and leaving the concrete, such as is the case in tidal waters or just about the water level where the waves are washing.

The only means of counteracting this influence is to make the concrete as dense as possible. It is in the interstices between the Sand-particles that the cement is exposed to the attack of the magnesium in the water, and it is through the interstices that the water flows in and out, washing away the insoluble hydrates and consequently laying bare new surfaces of cement to the attack.

By a careful mixing of pebbles, or the like, and of gravel and sand, so that all sizes of particles are represented, and all the interstices between the larger particles are everywhere filled up by smaller particles, something is certainly gained in the way of reducing the interstices. But still there are always the insterstices between the smallest particles which have to be filled with cement, and in which the cement is open to the attack.

Absolute impenetrability is, according to Dyckerhoff (1882), only secured by one cement and one sand under ordinary circumstances, and this means a heavy expense in cement.

In the case of the Sandcement the smallest particles of sand are those of the ground sand, and they are necessarily extremely minute, the Sandcement being ground to such fineness as only to leave 10 p.c. residue on a sieve of 32,000 meshes to the square inch. When enough of Sandcement is used to fill all the interstices between the ordinary sand in the concrete, it will be seen that great density is obtained, and the ultimate interstices between the smallest sand particles so reduced in size as hardly to admit the sea water to the attack, and it is to be expected that these minute interstices will be filled with the insoluble hydrates before any damage is done.

If the concrete made with Sandcement should not prove to have the necessary absolute strength on account of the small quantities of cement contained therein, any combination of Sandcement and usual fine Portland cement may be used to meet all requirements. It is thus to be expected that either a great saving in expense or a great improvement in the impenetrability of the concrete or a combination of both can always be attained.

Trials in this respect have been instituted and are being carried on, but as the action of the sea water is slow, results of any value have naturally not yet been gained.

It may be of interest to add a few remarks on the manufacture of Sandcement. This, in its main features, is quite simple, viz., drying of the sand, mixing of this with good Portland cement of the trade, and then grinding of this mixture in specially constructed machines, in which alone the requisite fineness and the thorough mixing can be attained at a reasonable cost.

The manufacture should, of course, take place near the place of consumption, and near the road which the sand would naturally follow on its way there, as a great deal of the ready produce is sand, which does not well bear heavy freight expenses. It is not said that the Sandcement cannot bear freight expenses, but it is evident that the position of the works near the place where the product is to be used is always the best. On the other hand, the manufacture is such as must be carried on on a somewhat large scale. Local manufacture would only be advisable where large quantities are required, either permanently or for specially large constructions requiring large quantities of Sandcement. To produce Sandcement on quite a small scale would hardly pay, and in this is a certain protection against misuse or infringement of the patent.

Sandcement-Tests

Made by Henry Kelway Bamber, F.I.C., &c.

Late in the year 1893 Mr. Henry Kelway Bamber, F. I. C. &c., of 9, Victoria St., London, was charged with making a series of tests on "Sandcement" manufactured by the process patented by Messrs. F. L. Smidth & Co. of Copenhagen. In order to insure a perfectly fair and unprejudiced, judgment, Mr. Bamber selected a brand of English Portland cement, with out revealing its identity, packed it in barrels which were sealed and sent to the Sandcement-Works at Aalborg in Denmark. The seals were then broken in the presence of Mr. Bamber who personally controlled the weighing and mixing of this cement and usual clean seasand and their subsequent manufacture into Sandcement of different rates of mixture, and the final packing of same into sealed boxes, which he brought back with him to his laboratory.

In due course he delivered the following

REPORT:

Experiments with ordinary English Portland cement and with the same cement ground finely at Aalborg in my presence with varying proportions of sand (sand-cements) for

MESSRS. F. L. SMIDTH & CO., COPENHAGEN.

The English Cement used was exactly the same as that sent to
Aalborg and left 39 pct. residue on a 200 sieve—40000 sq. inch.
including . . . . . 8.7 — 76 - 5776 —
The standard sand used was the usual Leighton Buzzard sand
passing through a 20 sieve = 400 pr. sq. inch.
remaining on a 30 sieve = 900 pr. sq. inch.

All the Sandcement left about 3 per cent. residue on 200 sieve 40000 sq. inch. The proportions of sand, cements and water were taken by weight.

The water used was chilled rain water.

Experiment	Mixture by weight.			The mixture contains		Tensile strain lbs. pr. sq. inch.				Gauged with per Cent of water
	cement	sand	sand	cement	sand	7 days	28 days	3 months	12 months	
	Sandcement		not ground							
No 1	1		3	1	3	113	178	255		11
" 2	1	2	2	1	8	164	248	332		9
" 3*)	1	3	2	1	11	111	197	280		9
" 4	1	3	3	1	15	84.5	235	182		7
" 5	1	12	2	1	38	35	75	124		8
" 6	1		11	1	11		57	90		4
" 7	1		15	1	15		35	66		3.5

(Sign) HENRY KELWAY BAMBER, F. I. C., &c.

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*) With reference to this experiment, No. 3, it is of interest to note that the countless experiments made with Sandcements 1 : 3 : 2 and 1 : 2 : 3 which both contain 11 parts of sand to one of cement have proved that they are almost identical in respect of strength.

The 12 months tests are still in water and the results will be forwarded in the stated times.

We use the way of indicating the mixture of a mortar as e. g. 1 : 3 : 2 meaning one part Sandcement 1 : 3 with 2 parts coarse sand ; as Sandcement 1 : 3 contains one part cement + 3 of sand, ground together, 1 : 3 : 2 mortar will to each part cement have 3 of ground sand and 8 of coarse sand or 11 parts of sand altogether.

Accordingly the Sandcement 1 : 2 when used for mortar with 3 parts sand is superior to neat cement used with the same amount of sand.

Sandcement tests in fresh and sea-water now being continued at Boulogne by Mr. Feret.

All breakings are given in kilos per square centimeter.

Where kept.	Sandcement 1:6.				Sandcement (1:6):2.			
	7 days.	28 days.	90 days.	1 year	7 days	28 days	90 days	1 year
	Broke	Broke	Broke	Broke	Broke	Broke	Broke	Broke
One day in the air. for the rest in fresh water.	11 11½ 18	14 22½ 24	25½ 28½ 32½	35½ 36½ 38	6 6 6 6½	7 9½ 9½ 10	10 12½ 14½ 14½	14½ 15½ 18½ 21
	Av. 13.5	Av. 20.2	Av. 28.8	Av. 36 7	Av. 6.1	.Av. 9.0	Av 12 9	Av. 17.4
In the Air.	17½ 23½ 26	23 33 33½	31½ 34 34 35	38 49 52	5 7½ 9½ 10	11 11 13 15	15 16½ 19 20½	13 16 22 23½
	Av. 21 7	Av. 29.8	Av. 33.6	Av. 46 3	Av 8.0	Av. 12.5	Av 17.75	Av. 18.6
In the Air. *) but occasionally saturated with water.	14 18½ 19	30 33 34½	46½ 58 59	41 45 65	8 8½ 8½ 9	15½ 17 19½ 22	21½ 22 22½ 26½	27 32 37½ 40
	Av. 17 2	Av. 32.5	Av 54.5	Av. 50 3	Av. 8.5	Av. 18.5	Av. 23 1	Av. 34.1

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*) After 1, 3, 7, 14, 28 days, 2, 3 4, 5, 6, 8 and 10 months, from the first only dipped in water, later on left in the water for one day each time.

All breakings are given in kilos per square centimeter.

Where kept.	Sandcement 1:6.				Sandcement (1:6):2.			
	7 days	28 days	90 days	1 year	7 days	28 days	90 days	1 year
One day in the air, for the rest in sea-water, submerged.	Broke 17 19½ 20 20½	Broke 21 21½ 27	Broke 24 33 36	Broke 29 32 33	Broke 6 6 7 7	Broke 9 9½ 9½ 11	Broke 11 13 15½ 16	Broke 15½ 18½ 20 21
	Av19.25	Av. 23.2	Av. 31.0	Av. 31.3	Av. 6 5	Av 9 75	Av 13 9	Av. 18 7
One day in the air, 6 days in fresh water, for the rest in sea-water, submerged.	—	22½ 24½ 25	26 28 31	33 33½ 37	—	7 [illegible]½ 9 9	8 13 13½ 13½	14½ 16½ 18½ 19
	Av.	Av. 24.0	Av 28.3	Av. 34.5	Av.	Av 8.1	Av. 12.0	Av 17.1
One day in the air, for the rest in sea-water, in the surface	12½ 17 20½	17 21½ 27½	21½ 25 32	21 26½ 27½	4 5 5½ 6½	7½ 9 9 9	9½ 11½ 12 14	0 *) 0 6 7½
	Av. 11.7	Av. 22.0	Av 26 2	Av 25 0	Av. 5.25	Av. 8.6	Av11 75	Av. 3.4
One day in the air, 6 days in fresh water, for the rest in sea-water, in the surface.	—	17 17½ 25½	23½ 28 34	17½ 25½ 29	—	7½ 9 9½ 9½	9½ 12 13½ 15	5½ 10 11½ 17
	Av.	Av 20 0	Av. 28 5	Av. 24.0	Av.	Av 8 9	Av. 12.5	Av. 11 0

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*) Much weakened. Lime reduced and partly substituted by magnesia.

Report of mechanical tests of Sandcement by Dr. L. Erdmenger, Misbürg, Hannover, Germany :

No.	Mixture by weight			The mixt're cont'ns		Tensile Strength lbs. per sq. inch											Remarks
	Cement	Sand	Sand	Cement	Sand	In Water											
	S'd-C'm't ad.					2	3	4	5	8	10	12	15	18	24	40	Weeks
1	1	1	0	1	1	. .	370	. .	450	. .	. .	512	. .	. .	. .	740	
2	1	1	½	1	2	. .	300	. .	. .	. .	. .	405	. .	. .	. .	670	
3	1	1	1	1	3	. .	300	. .	. .	. .	. .	535	. .	. .	. .	610	
4	1	3	0	1	3	. .	. .	200	. .	276	306	. .	370		. .	484	
5	1	3	1	1	7	. .	. .	185	. .	. .	270	. .	. .	. .	. .	400	
6	1	3	2	1	11	. .	. .	135	. .	200	. .	. .	270	. .	. .	340	
7	1	3	3	1	15	. .	. .	114	. .	. .	185	. .	. .	. .	256	270	
8	1	15	0	1	15	85	. .	. .	. .	200	. .	. .	.	. .	276	300	
9	1	15	1	1	31	57	. .	. .	. .	. .	. .	. .	. .	92	142	171	
10	1	15	2⅓	1	52	. .	. .	.	. .	. .	. .	. .	. .	57	85	100	
In the Air																	
11	1	1	0	1	1	. .	426	.	470	. .	. .	555	. .	. .	. .	700	
12	1	1	½	1	2	.	306	. .	. .	. .	. .	426	. .	. .	.	625	
13	1	1	1	1	3	. .	342	. .	. .	. .	. .	483	. .	. .	. .	625	
14	1	3	1	1	7	. .		242	. .		370	.		. .	. .	525	
15	1	3	2	1	11	. .	. .	142	. .	206	. .	.	256	. .	. .	370	
16	1	3	3	1	15		. .	100	. .	. .	142	. .	. .	.	150	200	
17	1	15	0	1	15	71– 128	. .	. .	. .	167	. .	. .	. .	. .	. .	256	
18	1	15	1	1	31	. .	. .	. .	. .	. .	. .	. .	.	64	. .	128	
19	1	15	2⅓	1	52	. .	. .	.	. .	. .	. .	. .			80	71	

It is seen from the above that by adding standard sand to the already mixed Sandcement, results of such great strength are obtained as could not be got by mixing equally high proportions of sand to ordinary cement. Mixtures 1:7 and up to 1:15 can according to the above, in many cases, even where greater claims as to strength are made, safely be used, and equal in good qualities and strength mortars made in a much richer mixture in the ordinary way.

(Signed.) Dr. L. ERDMENGER.

Hannover, March, 1893.

WILLIAM H. BURR,
Consulting Engineer,
71 Broadway.

NEW YORK, May 18th, 1895.

MR. DANIEL E. MORAN,
Prest. Silica-Portland Cement Co.,
Long Island City, N. Y.

Dear Sir :—

I enclose herewith a copy of the Report (made under date of May 14th, 1895) of the tests of the Silica-Portland Aalborg and Rosendale cements made by me for W. W. Kenly, Gen. Manager of the United States Mortar Supply Co. of New York City, which copy is exact in every particular except that the column of percentages of water used has been introduced. Those tests were undertaken to determine the relative values of the neat cements named and their mortars with the given proportions of sand. I stated in my report to Mr. Kenly that the Silica Portland Cement was ground under my inspection on April 24th, 1895, at the works of the Silica-Portland Cement Company, at Long Island City, New York. On that day I had taken from the grinding cylinder prior to the grinding done in my presence a small lot of the Silica-Portland cement which it then contained and said to be composed of six parts by weight of Rockaway Beach dune sand and one part by weight of Aalborg Portland cement. The results of breaking briquettes made from the Silica Portland cement are indicated in the tabular statement by the words "previous to test." After having had taken from the cylinder that small lot of Silica cement there were weighed and put into the grinding cylinder in my presence three hundred pounds of Aalborg Portland cement and eighteen hundred pounds of clean dune sand from Rockaway Beach. Nothing else was put into the grinding cylinder from the time of starting at 3.46 p. m. until the grinding of the entire lot of 2100 pounds of sand and cement was completed at 5.30 p. m. The Silica-Portland cement of which the tested briquettes were made and which yielded the enclosed tabulated results with the exception already noted and indicated in the table, was taken from the last sack produced by the grinding in my presence on the date named. The table contains the requisite notes of explanation to make it clear in all points.

Very truly yours,
(Signed) WM. H. BURR.

COLUMBIA COLLEGE IN THE CITY OF NEW YORK,
DEPARTMENT OF CIVIL ENGINEERING,
CEMENT TESTING LABORATORY, MAY 15, '95.

Report of Tests for W. W. Kenly, Gen. Manager.

Standard Briquettes.

S. P. C. indicates Silica-Portland cement, composed of 1 part by weight of Aalborg Portland cement, and 6 parts by weight of clean Rockaway Beach sand.

All sand used in these tests was standard crushed quartz, except for the four briquettes noted.

All portions indicated in the table, are by weight.

Those briquettes not marked thus x were prepared by Mr. Moran's assistant, in Columbia College Testing Laboratory.

Age		Briquettes	Per Cent of water	Ultimate Tensile Resistance, pounds per sq. inch	Remarks
Air	Water				
1 day	6 days	Neat Aalborg	22%	592 x	
"	"	" "	"	594 x	
"	"	" "	"	597 x	
"	"	" S. P. C.	21%	138 x	
"	"	" "	"	133 x	
"	"	" "	"	148 x	
"	"	" "	18%	135	
"	"	" "	"	122	
"	"	" "	"	121	
"	"	" "	"	113 x	Small air-holes
"	"	" "	"	126 x	
"	"	" "	"	102 x	Broke in the head
"	"	" "	19%	112 x	Sample from mill previous to test
"	"	" "	"	112 x	
"	"	" "	"	113 x	
"	13¾ days	" "	18%	170	
"	"	" "	"	164	
"	"	" "	"	172	
"	"	" "	19%	147	
"	"	" "	"	164	
"	"	" "	"	170	
"	13 days	" "	19%	132 x	
"	"	" "	"	140 x	
"	"	" "	"	141	
"	"	" "	"	134	Sample from mill previous to test
"	"	" "	16%	148	
"	"	" "	"	163	
"	3 days	1 part S. P. C. & 2 parts sand		56 x	
"	"	" "		46 x	
"	6 days	" "	11%	64	Ordinary beach sand, passed through No. 20 sieve and caught on No. 30.
"	"	" "	"	66	
"	"	" "	"	62	
"	"	" "	"	52	

Age		Briquettes	Per Cent of water	Ultimate Tensile Resistance, pounds per sq. inch	Remarks
Air	Water				
1 day	6 days	1 part 2 parts S. P. C. & Sand	11%	72	
"	"	" "	"	79	
"	"	" "	"	81	
"	"	" "	"	63	
"	"	" "	"	70	
"	"	" "	9%	88	
"	"	" "	"	90	
"	"	" "	"	98	
"	"	" "	10%	80	
"	"	" "	"	91	
"	"	" "	"	64	
"	"	" "		68 x	
"	"	" "		74 x	
"	"	" "		80 x	
"	"	" "	11%	61	
"	"	" "	"	58	
"	"	" "	"	63	
"	"	" "	"	70	
"	"	" "	"	74	
"	"	" "	"	78	
"	"	" "	"	67	
"	"	" "	"	75	
"	"	" "	"	68	
"	"	" "	"	70	
"	"	" "	"	78	
"	"	" "	"	72	
"	"	" "	"	62	
"	"	" "	"	71	
"	"	" "	"	69	
"	"	" "	"	70	
"	"	" "	"	62	
"	"	" "	"	62	
"	"	" "	"		
"	13 days	" "		87 x	
"	"	" "		108 x	
"	13¾ days	" "	9%	98	
"	"	" "	"	108	
"	"	" "	10%	104	
"	"	" "	"	108	
"	6 days	Neat N.Y.& Rosendale	27%	118	
"	"	" "	"	111	
"	"	" "	"	113	
"	"	" "	"	103	
"	"	" "	"	109	
"	"	" "	"	109	
"	3 days	1 part 2 parts N. Y. & R and Sand	12%	26	
"	"	" "	"	30	Brooklyn
"	6 days	" "	"	34	
"	"	" "	"	33	Bridge
"	"	" "	"	38	
"	"	" "	"	38	Brand
"	3 days	" "	10%	21	
"	"	" "	"	13	
"	6 days	" "	"	16	
"	"	" "	"	16	
"	"	" "	"	16	
"	"	" "	"	17	

(Signed) WM. H. BURR.

Additional report made to Daniel E. Moran by Wm. H. Burr :

SILICA PORTLAND CEMENT.

Tests of 8 Briquettes (1.6) Neat				
Days			Pounds per Square Inch	
in air	in water			
1	198	Average 190 days	308	Average 280 lbs.
1	189		264	
1	188		294	
1	184		260	
(1.6).2				
1	202	Average 196 days	221	Average 216 lbs.
1	202		194	
1	190		221	
1	190		229	

Silica Portland Cement used in the foundations of the Cathedral of St. John the Divine :

Averages From 2105 Briquettes, Broken						
	7 Days	14 Days	28 Days	90 Days		
5782 barrels of Silica Portland Cement (1.1) mixed with 3 parts sand	Average of 1094 briq's 156 lbs. per sq. inch	Average of 211 briq's 188 lbs. per sq. inch	Average of 800 briq's 200 lbs. per sq. inch	Average of 110 briq's 233 lbs. per sq inch		
Averages of 10060 barrels of foreign Portland cement . . . . . . brand mixed with 3 parts sand	Average of 1451 briq's 140 lbs. per sq. inch	Average of . . . briq's 199 lbs. per sq inch		Average of 6 briquettes 314 lbs. per sq. in ch		
Averages of 5148 barrels of foreign Portland Cement . . . . . . brand mixed with 3 parts sand	Average of 575 briq's 134½ lbs. per sq. inch	Average of . . . briq's 142½ lbs per sq. inch	Average of . . . briq's 179½ lbs. per sq. inch			

All the above tests were in accordance with the rules recommended by the Committee of the American Society of Civil Engineers.

Tests for crushing strength made on 6 in. cubes of concrete, made of one part Silica Portland cement (1.1), two parts sand, and three parts gravel. The concrete was taken from the bucket just as it was ready to be laid in the foundations of the Cathedral of St. John the Divine.

Each result is the average of the crushing strengths of four separate cubes, made under exactly the same conditions at different periods:

7	days old	crushed at	77,162 lbs.
14	"	"	83,225 "
30	"	"	92,465 "

Average tests made in accordance with rules recommended by Committee of American Society of Civil Engineers, of Silica Portland cement, made at the factory of "The Silica Portland Cement Co." at Long Island City, N. Y., during the year 1895, and reported by Daniel E. Moran, President of the company:

	7 Days	14 Days	28 Days	84 Days		
Silica Portland cement (1.1) with 2 parts sand Ironclad Portland cement used	349 lbs. per sq. inch	396 lbs. per sq. inch	429 lbs. per sq. inch	544 lbs. per sq. inch		
Silica Portland cement (1.1) with 2 parts sand Average of all brands of Foreign and American Portland cement used during year 1895	262 lbs. per sq. inch	312 lbs. per sq. inch	333 lbs. per sq. inch	410 lbs per sq. inch		